SEMI-ANNUAL REPORT

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California Institute of Technology

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This is a report on work under NASA grant NGR 05-002-281, "Far-Infrared Observations of H II Regions and Associated Galactic and Extragalactic Sources," for the time period November 1, 1978 - May 31, 1979.

I. OBSERVATIONAL RESULTS

A. Summary

During this time we participated in four KAO flights, which formed a "miniexpedition" to Hawaii in May 1979. These flights were extremely productive scientifically. The principal observational results include maps at 50 μm and 100 μm with 1' resolution of a region around the Galactic center about 1/2° in extent; higher resolution (30") maps of the central ~ 5' of the Galaxy at 30, 50, and 100 μm; 1' resolution maps at 50 μm and 100 μm of a reflection nebula, NGC 7023; and studies of infrared sources associated with molecular clouds, including Cep A and NGC 6589. The 1' resolution, 50 μm and 100 μm work was done in collaboration with S. Whitcomb and R. Hildebrand of the University of Chicago, and the molecular cloud observations were a collaboration with N. Evans of the University of Texas. E. Becklin and several of his colleagues from the University of Hawaii also participated in the flights.

B. Galactic Center - High Spatial Resolution

A preliminary analysis has been carried out on the data on the Galactic center. The high resolution observations probe the nature of the luminosity sources and the distribution of dust in the central 1 pc of the Galaxy which is the region of highest stellar density in the Galaxy. The results show that the emission from this region is unresolved at 30 μm but extended, and elongated along the galactic plane, at both 50 μm and 100 μm. Our previous C-141 work with 1' resolution (Gatley et al., Ap. J., 216, 277, 1977) suggests that much of the 50 μm and 100 μm emission is radiation from dust heated by the late-type stars at the galactic center. The present higher resolution observations, which join smoothly with our previous data, suggest that heating by late-type stars is the main source of the radiation at these wavelengths in the innermost portion of the Galaxy. The different appearance of the source at 30 μm suggests that a different stellar distribution, perhaps associated with the sources which ionize the Sgr A H II region, heats the dust which radiates at this wavelength.

The latest results corroborate an important result of the previous experiment, which is that the dust density in the central few pc of the galaxy is low and uniform. This is surprising in view both of the high density of evolved stars, which are expected to return dust to the interstellar medium, and of the fact that the density of stars increases inward, even on the scale of the present observations. The low density of dust manifests itself as a low far-infrared optical depth. It is instructive to compare the far-infrared surface brightness, color temperature, and optical depth of Sgr A with similar quantities which were measured for the H II region/molecular cloud complex W49 with the same system on the same flight. This is done in the table below.

TABLE 1

COMPARISON OF INFRARED EMISSION FROM CENTRAL 30" OF W49 AND SGR A

	Sgr A	W49	Sgr A/W49
30 μm Flux (Jy)	4000	1500	2.7
50 μm Flux (Jy)	3000	10^4	0.3
100 μm Flux (Jy)	3000	1.5×10^4	0.2
Total Flux at Earth 25-140 μm (W m^{-2})	3.4×10^{-10}	6.8×10^{-10}	0.5
Flux Ratio (50μm/100 μm)	1.0	0.67	-
Color Temperature (50 μm-100 μm) K	75	60	-
Optical Depth (50 μm)	0.03	0.36	0.08

The comparison clearly illustrates that Sgr A is much hotter, and has much lower far-infrared optical depth, than does W49. This underscores the differences between the Galactic center and a typical H II region/molecular cloud complex. It is also clear that the temperature information obtained from the present multicolor observations is crucial in distinguishing between the properties of these two sources.

C. Galactic Center - Low Spatial Resolution

Maps were made at both 50 μm and 100 μm of a region some 1/2° in extent around the galactic center. The observations were made with a detector array constructed by the University of Chicago group. The array had 3 spatial channels (~ 1' fields of view separated by ~ 1'); each spatial field was viewed simultaneously by two detectors operating at 50 μm and 100 μm. The observations consisted of azimuth scans ~ 45' in

extent, approximately perpendicular to the galactic plane, which were spaced by ~ 2' in elevation. Seventeen scans were made to sample fully a region, centered at Sgr A, more than 30' in extent in both right ascension and declination. The scans were carried out by tracking, and using an automatic scan routine, on the acquisition camera. This is a novel observing technique which had not been previously used but is well suited to our purposes. The data were stored on magnetic tape and the scans have been deconvolved in the CAVE with the cooperation of the ADAMS personnel.

Since the data reduction has just been completed, the results of the observations cannot yet be evaluated. It is hoped that the observations will lead to better understanding of the far-infrared emission from the center of the Galaxy and the distribution of luminosity sources and matter in the central ~ 100 pc of the Galaxy. For example, a comparison of the far-infrared data with the distribution of ionized and molecular gas, and of late-type stars (as inferred from the 2 μm emission) over the same region will determine the relative contribution of the several stellar populations to heating the dust which radiates the far-infrared emission. The unique features of the present observations which make this type of analysis possible are the spatial resolution of 1', which facilitates the comparison with the other observations made with this resolution, and the temperature information available from the observations at two wavelengths. An interesting preliminary result apparent in the raw data is that the 50 μm to 100 μm flux ratio is much higher to the north of the galactic center than at similar positions to the south of the center along the plane. This is suggestive of a large scale asymmetry in the distribution of one or more of the constituents listed above.

It is noteworthy that the spatial scale of the present observations is $\gtrsim$ 100 pc, which is comparable with the scale over which far-infrared observations of the nearest external galaxies are possible. Thus these observations should contribute to our understanding of these more distant objects as well.

D. Other Observations

The observations of NGC 7023 are among the first systematic far-infrared observations of a reflection nebula; NGC 7023 has been well studied at optical wavelengths. It is likely that the grains radiating in the far infrared are the same which reflect the optical radiation and comparison of the optical and infrared observations may provide significant new constraints on both the properties of the grains and the geometry of the reflection nebula.

The molecular cloud observations include cases where a molecular peak appears to contain an internal heat source, perhaps a protostar, and cases where the molecular cloud is heated from the outside, for example by the exciting stars of an H II region which has formed in the edge of the cloud. Since these are two of the principal mechanisms discussed for the heating of molecular clouds, it is of considerable interest to see whether far-infrared observations can in fact distinguish between them.

II. DATA ANALYSIS AND PUBLICATIONS

A large number of papers resulting from observations carried out in our C-141 program have been published, submitted, or brought close to completion in the past few months. These are listed below.

A. Papers Published

1. "An Upper Limit to the Far-Infrared Emission from the Crab Nebula," P. M. Harvey, I. Gatley, and H. A. Thronson, P.A.S.P., 90, 655 (1978).
2. "Star Formation at a Front: Far-Infrared Observations of AFGL 333," H. A. Thronson, P. M. Harvey, and I. Gatley, Ap. J. (Letters), 229, L133 (1979).
3. "Infrared Observations of OH205.1-14.1 and AFGL 450: Two Possible Low Luminosity Protostars," P. M. Harvey, M. F. Campbell, W. F. Hoffmann, H. A. Thronson, and I. Gatley, Ap. J., 229, 990 (1979).

B. Papers Accepted for Publication

4. "Far-Infrared Observations of M17: The Interaction of an H II Region with a Molecular Cloud," I. Gatley, E. E. Becklin, K. Sellgren, and M. Werner, Ap. J., in press.
5. "An Infrared Study of the NGC 7538 Region," M. Werner, E. E. Becklin, I. Gatley, K. Matthews, G. Neugebauer, and C. G. Wynn-Williams, M.N.R.A.S., in press.
6. "New Multiple Systems in Molecular Clouds," C. A. Beichman, E. E. Becklin, and C. G. Wynn-Williams, Ap. J. (Letters), in press.
7. "Far-Infrared Observations of Emission Line Stars: Evidence for Extensive Cool Dust Clouds," P. M. Harvey, H. A. Thronson, and I. Gatley, Ap. J., in press.

C. Papers Close to Completion

8. "The Infrared Emission of G333.6-0.2, An Extremely Nonspherical Region," A. R. Hyland et al.
9. "Simultaneous Far-Infrared, Near-Infrared, and Radio Observations of OH/IR Stars," M. W. Werner et al.
10. "IC 342: An Infrared Galaxy of Intermediate Luminosity," C. G. Wynn-Williams et al.
11. "Mon R2: Far-Infrared Observations of a Very Young Cluster," H. A. Thronson et al.